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Novel laser sources for space-based LIDAR and communications applications

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Abstract: *In recent years NASA GSFC has been developing advanced laser and photonics technologies for spaceborne remote sensing and laser communications applications. Here, we will discuss recent progress on these system for future missions.*

1. Introduction

NASA Goddard Space Flight Center (GSFC) has been developing advanced novel laser sources for lidar with path for space deployment in the past few years. In this paper, we will discuss recent progress on lidar and laser communication technologies development for future mission opportunities.

2. Diverse Interests

NASA GSFC has successfully flown missions based on matured diode pumped solid state lasers (DPSSL) for Earth and planetary sciences. These types of laser system designs have space heritage, can be easily scaled for specific use, and can be ruggedized for space deployment. However, demands for wavelengths spanning from UV to mid-infrared (MIR) to meet a broad range of science goals as well as continual development of instruments for smaller satellite platforms are high and often cannot be easily met using traditional DPSSL.

We have been developing several new, space-based laser instruments that involved DPSSL and fiber-based laser technologies to satisfy a vast variety of remote sensing missions. These include lidars for remote sensing of carbon dioxide and methane on Earth for carbon cycle and global climate change; laser communications; gravitational waves detection based on laser ranging interferometers; new generation of multi-wavelength altimetry and in situ laser instruments include potential use of ultra-short pulse generation for time-of-flight mass spectrometer (TOFMS) to study the diversity and structure of nonvolatile organics in solid samples on missions to outer planetary satellites and small bodies.

3. Requirements and Aproaches

A common goal among these different instrument designs is the ability to meet the needed laser requirements with limited available resources. The available resources for orbiting satellites for global coverage or *in-situ* instruments for lander platforms are vastly different and the design approaches for each need to be considered from the conceptual design phase. The size, weight and power (SWaP) and most often, cost (SWaP-C) becomes a metric whether a specific design can be adopted for certain flight missions. Previously launched DPSSL for orbiting satellites have wall plug efficiency (WPE) typically in the <4% range with pulse repetition frequency (PRF) below a hundred Hz. These cannot be easily adopted for lander applications, or the cadence of measurements must be reduced to meet the limited lander resources. Also, for orbiting satellites, a potentially new trend of using high PRF lasers, which are more suitable for fiber lasers, is generating a lot of interests as seen in the recent success on the ICESat-2 mission. The ICESat-2 mission uses a micropulse lidar concept where a high PRF laser operating at 10 kHz is used with WPF ~5%.

Another demanding requirement is the laser lifetime and reliability for spaceborne applications. To meet the mission lifetime requirements, the laser needs to be de-rated and have ample margin. This often lowers the WPE of the system.

4. Novel Laser Systems for Future Space Applications

Generation of specific wavelengths meeting various science disciplines' objectives are usally done with harmonic generations or optical parametric generation.

For example, for planetary science, we have demonstrated 4th and 5th harmonic generation of 1064 nm wavelength in support of novel instruments to comprehensively characterize the composition of the planetary surface and/or near-subsurface materials. We have flown a few airborne campaigns with fiber-based laser transmitters with very large core gain fiber for carbon dioxide (CO_2), and OPO/OPA for methane (CH_4). For other programs such as sodium lidar for heliophysics we have been developing optical non-parametric processes such as Raman process to generate 589 nm matching the sodium D_{2a} spectrum for temperature measurements in the mesosphere. Recently launched Lunar Laser Communication Demonstration (LLCD) and Lunar Communications Relay Demonstration (LCRD) both based on 1.5 µm telecommunications laser transmitters and fiber components.

5. Conclusions

In this paper I will present development progress on a few novel laser concepts for future flight opportunities with the goals of lowering SWaP and increasing reliability. NASA continues to develop systems to meet increasing demands on a wide range of spectral interests to meet different science goals.